

THE PROCEEDINGS OF THE ROYAL ENTOMOLOGICAL SOCIETY OF LONDON

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AN APPARENT INVASION OF *AËDES* (*BANKSINELLA*)
LINEATOPENNIS AND *AËDES* (*B.*) *ALBICOSTA* INTO
 MOMBASA ISLAND.

By C. TEESDALE, B.Sc., F.R.E.S.

THE following is a brief account of the sudden appearance in Mombasa, Kenya, of large numbers of *Aëdes* (*Banksinella*) *lineatopennis* (Ludlow) and *Aëdes* (*B.*) *albicosta* Edwards on the morning of 10th January, 1944, during routine anti-mosquito measures carried out by the Public Health Department.

Mombasa Island has an area of five square miles and is situated in 4° 04" south latitude, 30° 40" east longitude on the east coast of Africa. It is separated from the mainland on three sides by a channel one-third to three-quarters of a mile in width and by two large inlets. Bridges connect with the mainland on the north and east.

By January the north-east trade winds, increased by the Indian north-east monsoon, are well established and blow strongly from about mid-December to mid-March. This period is characterized by almost complete drought. From about 10 a.m. to 10 p.m. every day the winds are high, but decrease rapidly after 10 p.m. and may be absent altogether during the night or replaced by a light, indefinite land breeze. During the change in the Monsoon from mid-March precipitation is heavy until the south-east monsoon is established about mid-June. About mid-December the north-east monsoon begins and the so-called "short rains" occur in November and December. This is more clearly shown by reference to Table I.

TABLE I.—*Meteorological Data. Mombasa. Average Figures over a Period of Ten Years.*

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Precip.	1.02	0.66	2.56	7.32	12.65	4.53	3.84	2.42	2.55	3.21	3.91	2.33
Rel. hum.	71	69	72	73	81	76	77	77	76	71	71	73
Mean max.	87.8	89.9	91.1	89.8	83.3	83.3	82.0	82.3	83.4	85.7	88.6	88.6
Mean min.	76.1	77.2	78.4	77.8	74.5	73.1	71.8	71.4	72.2	73.9	75.6	75.8

Routine catches of adult mosquitoes in outside harbourages from different localities were begun in 1942, and a few *Aë. lineatopennis* and *Aë. albicosta* had always figured in these captures. The monthly seasonal prevalence of males and females is indicated in Tables II and III. The numbers of Africans engaged on this work was not always the same. For this reason a rough index was obtained by dividing the number of adult mosquitoes captured each month by the man-days, a day consisting of five hours (7 a.m. to 12 noon). The monthly catches and indices are given in Table II. Females predominate; a condition probably accounted for by their proclivity for human blood on which they feed readily in bright sunshine.

TABLE II.—*Aedes lineatopennis*: Captures and Indices.

Month.	1943. ¹			1944.			1945.			1946.			1947.			1948.		
	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.
Jan.	3	78	0.28	282	4984	16.2	34	61	0.4	4	150	1.1	1	9	0.1	20	47	0.8
Feb.	—	16	0.05	24	123	0.8	—	6	0.3	—	4	0.2	—	2	0.2	—	2	0.4
March	177	217	1.6	9	52	0.2	13	999	3.5	2	4	0.6	1	41	0.3	—	4	0.16
April	72	344	1.7	27	775	4.4	38	589	2.1	4	120	0.81	27	301	2.5	3	216	3.7
May	52	212	1.0	156	292	2.0	—	15	0.3	16	263	1.9	15	27	0.3	16	60	1.0
June	26	52	0.3	13	42	0.2	—	9	0.8	5	116	0.7	3	16	0.1	—	5	0.03
July	4	53	0.2	1	55	0.3	6	114	0.5	80	291	2.0	—	8	0.5	—	1	0.02
Aug.	—	1	—	—	8	0.04	3	41	0.1	2	55	0.25	13	21	0.2	—	21	0.4
Sept.	—	1	—	a	—	—	—	1	—	—	10	0.05	8	8	0.1	14	14	0.6
Oct.	—	—	—	—	—	—	—	—	—	9	595	2.6	1	1	0.01	12	49	1.2
Nov.	—	1	0.02	76	301	1.8	1	4	0.02	254	657	3.4	—	—	—	55	128	3.2
Dec.	48	442	1.8	99	324	1.6	29	91	1.0	61	175	1.2	—	5	0.06	50	96	2.7

¹ See note to Table III.² In September and October, 1944, catches were stopped.TABLE III.—*Aedes albicosta*: Captures and Indices.

Month.	1944. ¹			1945.			1946.			1947.			1948.		
	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.	M.	F.	Ind.
Jan.	21	758	2.4	26	65	0.4	—	49	0.4	—	6	0.07	3	8	0.1
Feb.	2	46	1.6	—	5	0.2	—	7	0.03	—	1	—	—	—	—
March	6	31	0.1	3	194	0.7	—	8	0.05	2	24	0.15	—	1	—
April	—	180	0.9	3	173	0.6	1	8	0.06	4	44	0.3	—	2	0.03
May	26	132	0.7	—	24	0.5	4	25	0.2	—	8	0.05	—	—	—
June	13	42	0.2	—	9	0.8	—	14	0.8	—	1	—	5	4	0.06
July	—	7	0.03	5	26	0.1	6	44	0.25	—	2	0.01	—	—	—
Aug.	1	12	0.06	1	13	0.04	1	5	0.03	—	9	0.05	5	4	0.2
Sept.	—	—	—	—	—	—	—	4	0.02	—	1	—	4	0.08	—
Oct.	—	—	—	1	1	—	30	113	0.6	4	4	0.06	—	—	—
Nov.	15	100	0.6	3	5	0.03	—	123	0.5	2	1	0.06	—	—	—
Dec.	14	48	0.2	3	61	0.6	4	35	0.2	1	3	0.05	—	—	—

¹ The apparent absence of *Aë. albicosta* in 1943 was due to an error in identification, the mosquito being confused with *Aë. lineatopennis*. Thus the figures for *Aë. lineatopennis* (Table I) include *Aë. albicosta*.

Both mosquitoes show a seasonal increase at the beginning of the long rains (March, April, May) and during the short rains (October, November, December), more marked in the case of *Aë. lineatopennis*.

Mombasa Island and the surrounding mainland afford little opportunity for mosquito breeding on a large scale, as all temporary collections of water within the municipality are oiled, and more permanent foci such as swamps and seepages have been drained. However, outside the municipal boundary there are a number of shallow swamps on an impervious shale which hold water all the year round except during the very dry weather from January to March.

In December, 1943, and the early part of January, 1944, the usual increase of captures of *Aë. lineatopennis* had been noticed; but on 10th January, quite suddenly, the whole island was infested. Captures on the mainland within a radius of about two miles of the island were just as heavy and densities did not appear to vary in different localities, except only in so far as the adults tended to collect together under the shade of large trees. Large numbers were caught by the writer on the following day in a village about ten miles to the north of Mombasa.

The infestation lasted about three days, after which the numbers declined rapidly. Unfortunately the numbers captured before, during and after these three days are not available, but fig. 1, showing graphically the monthly captures for 1943 to 1945, brings out the sudden enormous increase in January, 1944, a month when catches are invariably small. Even the figures of 282 males and 4984 females captured in January, 1944, do not truly reflect the

intensity of the infestation, since the catchers were issued with a limited number of tubes for collecting the adults; when the tubes were full the men had perforce to stop catching.

It was noticed that the adults appeared to be in small clusters in shady situations outside. But they were also seen in very large numbers in all houses examined. Those in houses did not appear inclined to feed, but outside the writer's legs were covered with voracious mosquitoes in a few seconds if he stood still for a moment.

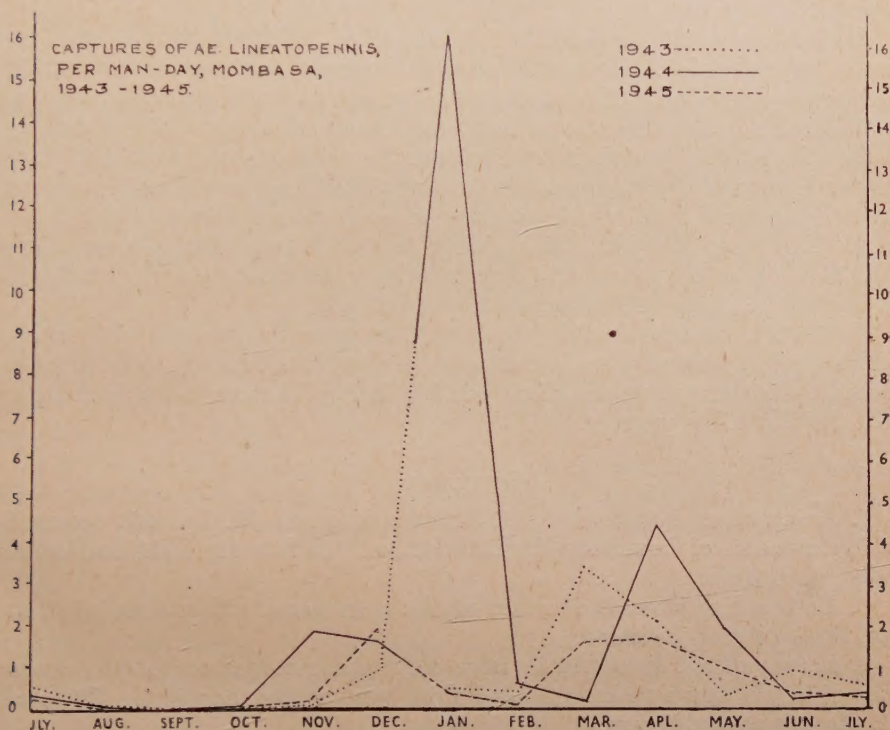


FIG. 1.—Monthly captures of *Ae. lineatopennis* per man-day, Mombasa, 1943-1945.

DISCUSSION.

The only permanent water within a distance of about 8 miles from Mombasa is in the form of two small rivers, the Mwachi and the Kombeni, which empty into the two large inlets to the north-east and north-west of the island respectively. No indications of breeding were noted in swampy patches near their outflows. All temporary swamps were dry. Furthermore, there had been a virtual drought the year before and only 0.21 inches of rainfall had been recorded in December. Relative humidity had been lower and temperatures higher than in any other season of the year. In fact conditions for mosquito activity could scarcely have been less favourable and captures of all other mosquitoes had been extremely low.

Larvae of *Ae. albicosta* have not yet been recorded anywhere and those of *Ae. lineatopennis* are commonest in pools in marshy ground or at the edges of

swamps and only found after heavy rain (Hopkins, G. H. E., 1936). Larvae of *Aë. lineatopennis* have only been recorded at Mombasa on four occasions (three times in pools in 1936/7 and once in a tin (1942)); all were found on the mainland.

It is known that both species of the subgenus *Banksinella* are strong fliers and it can be asserted almost with certainty that no breeding was taking place within an area of three miles radius from the island. The adults must have crossed the channel surrounding the island; it is anything between one-third to one mile in width.

It therefore seems certain that the infestation was in the form of an "invasion" or migration. It was not possible, however, to ascertain from which direction it originated. That mosquitoes can and do travel up-wind has been established, so that the strong north-east monsoon might not necessarily obviate the possibility of their coming from the south or south-west, and since the wind drops at night, they could have advanced from any direction except from the seaward side. Since captures of both species here considered are taken throughout the year, their ability to travel long distances and their habit of doing so does not seem to be in question; but the factors which induced the sudden and large infestation are not understood.

Vegetation consists of patchy bush and long grass interspersed with native cultivation; a coconut palm belt fringes the coast line from half to three miles in depth. Such cover would afford suitable shelter for mosquitoes working in from their breeding grounds.

SUMMARY.

1. An apparent invasion of *Aë. lineatopennis* and *Aë. albicosta* occurred at Mombasa and on the surrounding mainland on 10th January, 1944, and lasted about three days.

2. No breeding grounds of either species were found within a radius of at least three miles of the island.

3. Larvae of *Aë. lineatopennis* have only been recorded on four occasions since 1936 (the last time in 1942) and these were on the mainland. Those of *Aë. albicosta* are not known.

4. The invasion occurred during the off-season and subsequently to exceptionally dry conditions.

REFERENCES.

- HOPKINS, G. H. E., 1936, *Mosquitoes of the Ethiopian Region. Part. I. Larval bionomics of mosquitoes and taxonomy of Culicine larvae.* London: Brit. Mus. (Nat. Hist.).
- SYMES, C. B., McMAHON, J. C., and TEESDALE, C., 1939, *Report on a Malaria Survey of Mombasa.* Government Printer, Nairobi.

LARVAE OF THE BRITISH TRICHOPTERA.—30.

By N. E. HICKIN, Ph.D., F.R.E.S.

Tinodes pallidula McLachlan (PSYCHOMYIDAE).

ON 26th June, 1949, I collected a batch of larvae from the stream which I have previously called the Nutfield stream, Surrey, at the point where it emerges from a culvert under the railway embankment. At this point the stream runs due north and is the parish boundary between Bletchingley and Nutfield. It is about a mile due south of Bletchingley village. The larvae were collected from the entrance to the culvert to a point about 20 yards north of this point. Although the stream was searched on this and subsequent occasions, larvae were not found except in the locality indicated above. Larval tunnels were found only on old alga-covered broken house bricks which were in all cases about an inch above water level at the time of collection. The porosity of the bricks, however, kept the tunnels damp on the outside and they were indeed found to be full of water.

A number of the larval tunnels were taken home intact on the broken house-bricks, and from 17th July to 1st August a number of males and females emerged in the jars in which I had maintained the larvae—the tunnels being about $\frac{1}{2}$ in. above the water level.

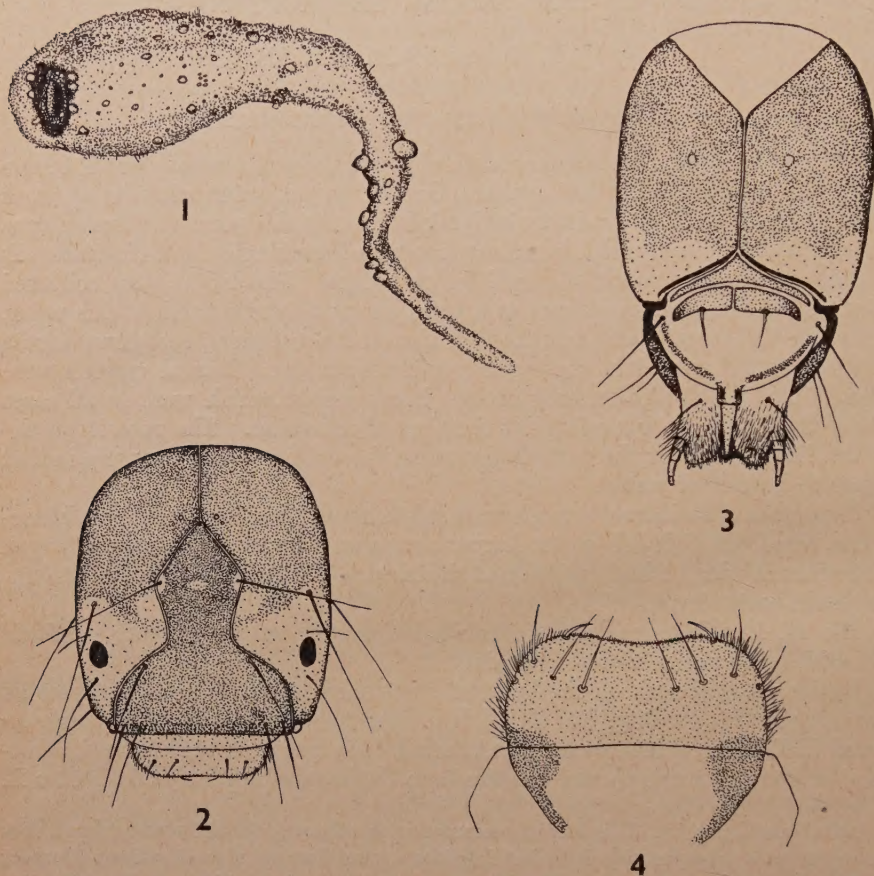
Mr. D. E. Kimmins kindly identified them for me as *Tinodes pallidula* McLachlan, a species new to Britain.

Besides the species of Trichoptera mentioned in this series of papers as occurring in this locality, Mr. D. E. Kimmins collected adults of *Micropterna sequax* McLachlan (this species I had reared from larvae in 1948 from the Outwood stream, Surrey), *Cyrrus trimaculatus* Curtis, and *Leptocerus bilineatus* L.

Larval tunnel (fig. 1): This larva in common with other species of PSYCHOMYIDAE does not construct a transportable case, but inhabits a tunnel made of sand grains with mud, algal filaments and occasional small pebbles cemented together with a silk-like secretion. Lower surface of the tunnel consists of the house-brick (on which tunnels were found), but coated with a thin layer of silk. Tunnel generally sinuous, posterior end tapering, the anterior end spatulate. Often difficult to observe when occupying concavities in the brick. Length very variable, often the current of the stream washes away the posterior part of the tunnel, leaving only the anterior spatulate part. Width of anterior end up to 6 mm.

Larva.—Campodeaform, head procentrous. Head and pronotum dark brown, remainder of body light yellowish green with large area on meso- and metanotum dark and with dark streak down centre of remainder of body—brownish to dark green. Length 8 mm., width 1.4 mm. Head and prothorax and posterior two abdominal segments narrower than remainder of body. The hinder four segments tapering. *Head* (figs. 2 and 3): Oval. Genae brown but region around eyes pale cream; ventral region also brown. Clypeus dark brown. Antennae very small. *Labrum* (fig. 4): Excision on anterior margin shallow. Light yellowish brown with dark brown areas in the hinder part of the lateral margins.

Mandibles (figs. 5a and 5b): Asymmetrical, both mandibles with two long bristles on outer edge, left mandible only with extensive brush of fine hairs on inner edge. Both mandibles have auxiliary teeth at base of inner edge. *Maxillae* (fig. 7): Palp four-segmented, third segment longer. Mala hairy, yellowish brown. *Labium* (fig. 6): Long and acicular, palps absent but pair of fine hairs on ventral surface, lateral sense organs situated between



FIGS. 1-4.—*Tinodes pallidula*. (1) Tunnel of larva (with pupal case within) after emergence of adult. (2) Head of larva from above. (3) Head of larva from below. (4) Labrum.

the hairs and the tip, and a transverse groove approximately half-way along the labium are well shown in this species. *Thorax* (fig. 8): Prothorax sclerotised, dark brown, but the four bristles in the centre of the pronotum arise from small light-coloured areas, the anterior pair larger than the posterior pair. Prosternal horn absent, but posterior margin of prosternum produced forward in the middle to form a large blunt sclerotised spine as in *Tinodes waeneri*. Meso- and metathorax not sclerotised, but with variable pattern of light-coloured streaks and spots formed by presence and absence of minute spicules. Prothoracic legs slightly more heavily sclerotised and more robust than meso- and meta-

thoracic legs. Bristles on tarsal claws of all legs in addition to spines. Fringe of hairs along entire hind margin of prothoracic tarsi. Anterior sclerite on trochantin of prothoracic legs not so large as in *Tinodes waeneri*. *Abdomen*: Intersegmentation deep. Lateral line absent, branchial gills absent, but five anal gills present. Variable pattern of light marks



FIGS. 5-9.—*Tinodes pallidula*. (5) (a) Left mandible; (b) Right mandible. (6) Labium, lateral view. (7) Head and prothorax, lateral view. (8) Thoracic nota. (9) Anal claw.

formed as in meso- and metanotum. *Anal claw* (fig. 9): Sclerotised ring at posterior margin of lobe of anal claw well shown in cleared specimens. The series of five or six spicules at base of claw not discernible.

Note on formation of cocoon (fig. 1).—When the larva is fully fed it constructs a cocoon of silk and small particles of sand, etc., which are well cemented together. This is constructed within the enlarged anterior part of the larval tunnel, and is adherent to the base of the tunnel. After the pupa has emerged the cocoon still remains firmly fixed in the larval tunnel.

SUMMARY.

The larva of *Tinodes pallidula* McLachlan (PSYCHOMYIDAE) is described in detail and figured. A note is given on cocoon formation.

REFERENCES.

- KIMMINS, D. E., 1949, *Tinodes pallidula* McLachlan, an addition to the British list of Trichoptera. *Entomologist* **82** : 269.
 McLACHLAN, R. F., 1878, *Tinodes pallidula* McL. *Rev. Syn. Trich.* : 419, pl. xliv.

BOOK NOTICES

The Hive and the Honey Bee. Edited by ROY A. GROUT with the collaboration of a staff of specialists. 8vo. Hamilton, Illinois (Dadant and Sons). Revised edn., 1949. Pp. xviii + 652, 303 figs. Price 32s.

This is a modern successor to *Langstroth on the Hive and the Honey Bee, a Bee-Keeper's Manual*, first published in 1853. It deals exhaustively with all aspects of bee husbandry, with the following chapters, each contributed by a specialist: the bee-keeping industry; races of bees; the honey-bee colony—life history; activities of honey bees; the honeycomb; beekeeping equipment; first considerations in keeping bees; the apiary; common practices in management; management for extracted honey production; extracting the honey crop; the production of comb honey; the production of bulk comb honey; the overwintering of productive colonies; honey; marketing the honey crop; the honey bee as a pollinating agent; sources of nectar and pollen; the anatomy of the honey bee; production and uses of beeswax; the production of queens and package bees; injury to bees by poisoning; diseases and enemies of the honey bee.

Les Insectes : 1. Coléoptères, Orthoptères, Archiptères, Névroptères. By PAUL-A. ROBERT. (Les Beautés de la Nature). Sm. 8vo. Paris, (Delachaux et Niestlé), 1946. Pp. 209, 32 col. pls., 74 figs. Price Sw. Frs. 12.00.

The first of two volumes reviewing eight insect Orders: Coleoptera, Orthoptera, Archiptera (= Odonata) and Neuroptera in volume I; Hymenoptera, Lepidoptera, Hemiptera and Diptera in volume II. The emphasis is on biology rather than on classification—the author says in his introduction: “la totalité presque absolue des espèces d'insectes, au moins dans nos pays, a été décrite et cataloguée, et sauf quelques variétés exceptionnelles ou locales il n'y a plus grand'chose à trouver dans ce domaine”!

The style is somewhat lyrical—“Voici comme un éclair une ombre qui passe . . .” and the work throughout conforms closely to the title of the series, *Les Beautés de la Nature*. The line-figures mostly illustrate breeding-habits or details of early stages. The fine fullpage coloured plates show specimen insects in natural surroundings, and are the principal feature of the book.

LARVAE OF THE BRITISH TRICHOPTERA.—31.

By N. E. HICKIN, Ph.D., F.R.E.S.

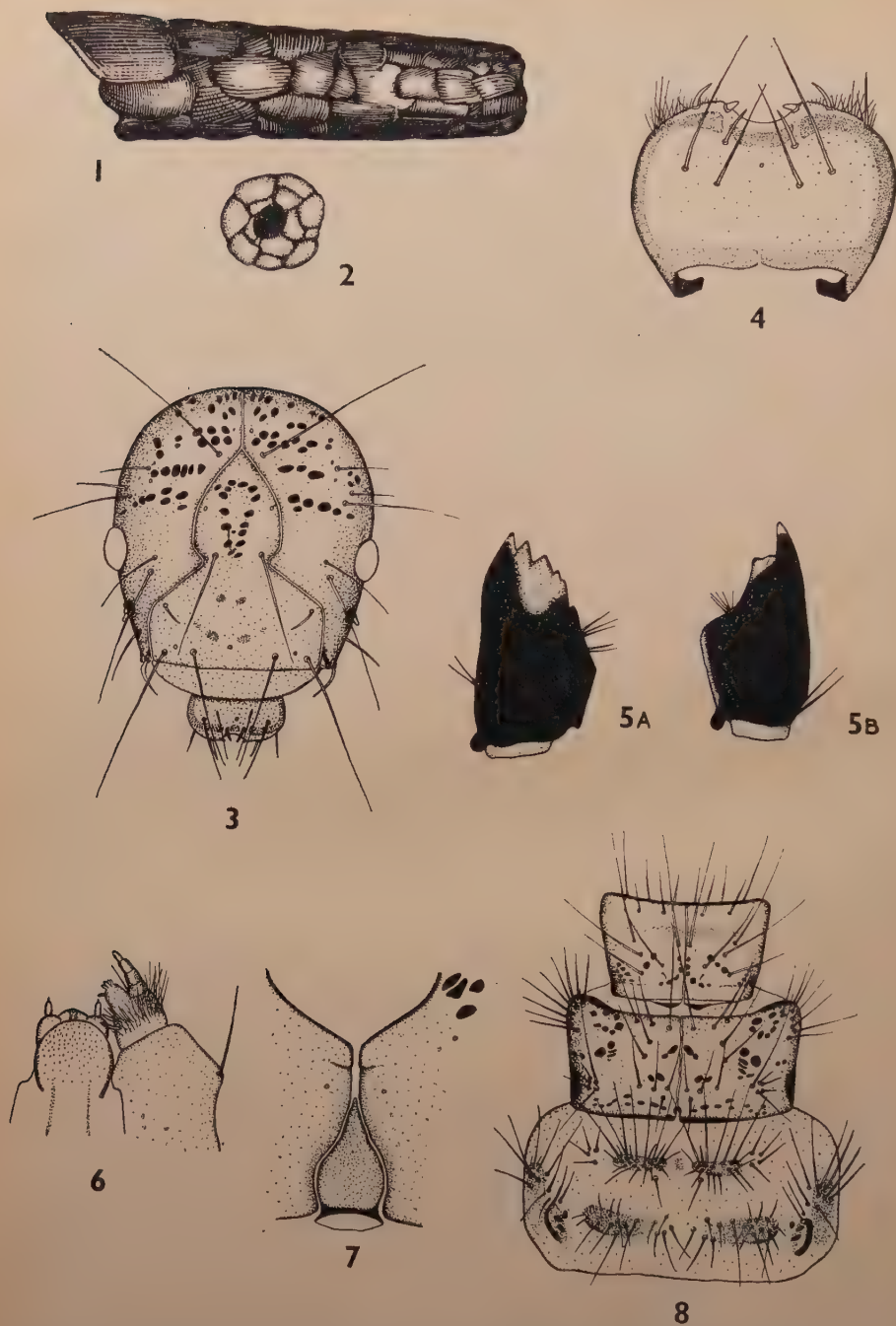
Stenophylax vibex Curtis (LIMNOPHILIDAE).

THIS large light-coloured caddis fly was familiar to me for three years before I discovered its larvae. Each year from the beginning to the middle of June these caddis alight on the lit windows of my home at Bletchingley, Surrey (550 ft. a.s.l.), but the nearest stream which their larvae could inhabit is just over one mile away. This is the stream at Nutfield, inhabited by *Halesus digitatus*, *Plectrocnema conspersa*, *Tinodes pallidula* and other species of caddis which I have already described in this series of papers, but not apparently by *Stenophylax vibex*. However, on 15th February, 1948, I did collect a number of larvae, some of which subsequently emerged on 6th June and were determined as *S. vibex* (confirmed by the late M. E. Mosely). These came from a stream near Outwood, Surrey, 220 ft. a.s.l., which is just two miles from my home, to which the fly is attracted by light. They were found together with the larvae of *Micropterna sequax*. The Outwood stream is fairly small, some 2 to 4 ft. in width, with a stony bottom alternating with patches of clay.

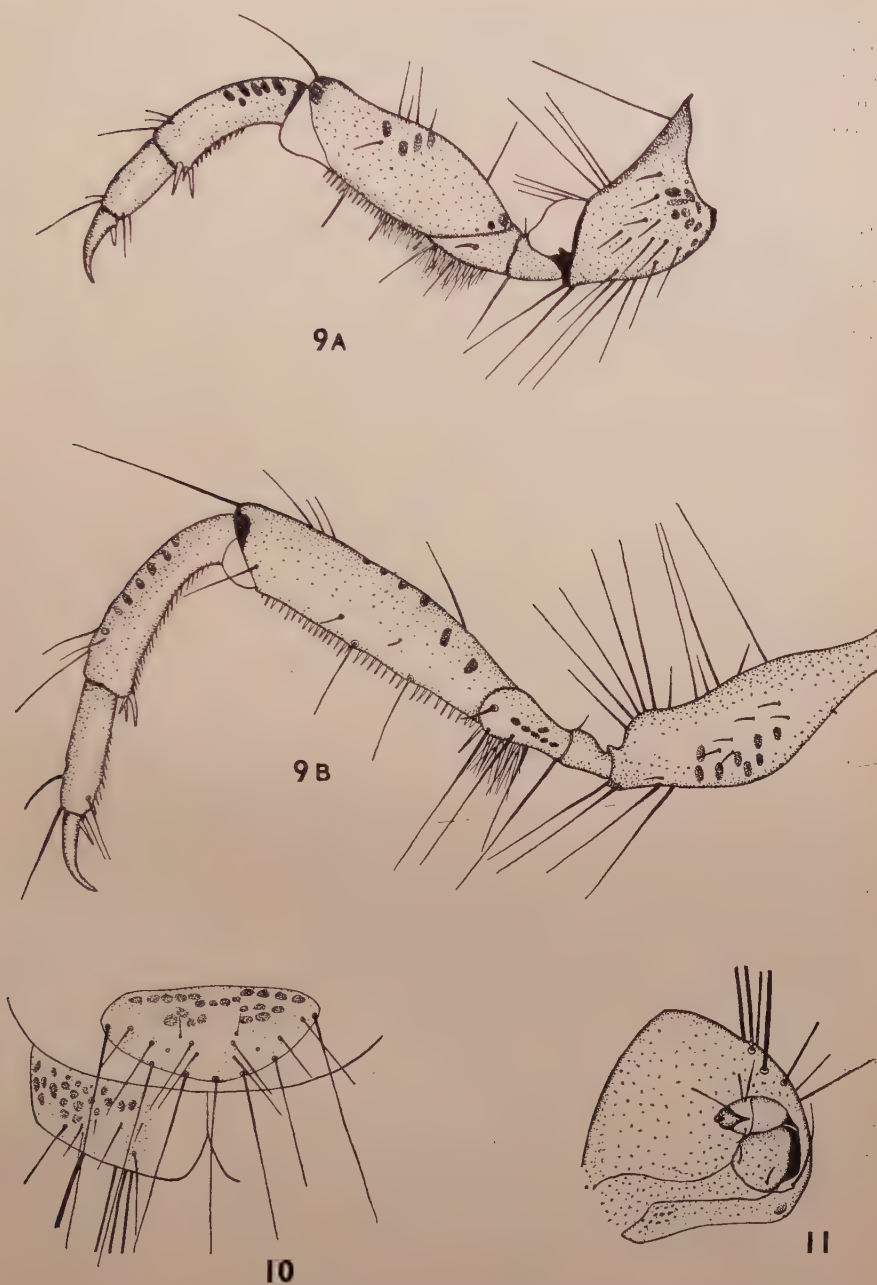
Before describing the larvae of *S. vibex* one characteristic of the living adult should be mentioned, and that is the streak of light golden buff which dominates the appearance of the insect in the resting position. This streak extends from the head backwards, traversing the length of the thorax and is continued by the hind margin of the fore wings, where they overlap on the dorsal surface of the abdomen. The streak appears to be a good example of disruptive coloration.

Case (fig. 1): Made of plate-like portions of vegetable debris, such as parts of dead leaves with no projecting edges, brown or black in colour. Length up to 12.5 mm., conical, tapering in width from 4.8 mm. at anterior end to 3.5 mm. at posterior end. Posterior end rounded and partly closed, leaving small opening only (fig. 2). No curvature of the case is apparent, nor is the ventral surface flattened as it is in *S. stellatus* and *S. latipennis*.

Larva.—Eruciform. Head orthognathous. Length 12.3 mm., width 4.0 mm. *Head* (fig. 3): Light brown shading to dark brown, with pattern of black spots (not usually symmetrical) forming transverse bands. Eyes well defined, antennae very small. *Labrum* (fig. 4): A deep excision on anterior margin; lateral margins and a small patch below the excision dark in colour. *Mandibles* (fig. 5) four-toothed; each has a small brush of hairs on inner margin. *Maxilla* (fig. 6) hairy at base, with outer distal part darker in colour and bearing a bristle which lies inside the four-segmented palp. Two thick light-coloured spines arise from the base of the mala. *Labium* globular, with proximal segment of two-segmented labial palp globular. *Gular sclerite* (fig. 7) not completely dividing the genae, together with the adjacent margins of the genae darker in colour than the ventral area of the genae. A small fold occurs at the ventral genal suture. *Thorax*: Pro- and mesothoracic tergites sclerotised with pattern of dark spots as shown in fig. 8. Pronotum constricted transversely near hind margin. Prosternal horn present. Metathoracic tergum partially sclerotised with bristles more numerous and larger than in *S. stellatus*. Prothoracic legs (fig. 9a) short; meso- (fig. 9b) and metathoracic legs long and similar; a



FIGS. 1-8.—*Stenophylax vibex*. (1) Larval case. (2) Posterior end of case. (3) Head. (4) Labrum from above. (5) Left mandible. (6) Labium and right maxilla. (7) Gular sclerite. (8) Thoracic nota.



FIGS. 9-11.—*Stenophylax vibex*. (9) Legs, (a) prothoracic ; (b) mesothoracic. (10) Anal sclerite. (11) Anal claw from below.

few dark marks on the distal segment of the trochanter. *Abdomen* greyish white, but first abdominal segment slightly darker and browner in colour, protuberances present on this segment but not large. A number of bristles present on the ventral surfaces of the first abdominal segment, each arising from a small dark circular patch. Filiform gills present. Anal sclerite (fig. 10) with pattern (somewhat variable) along anterior margin; the basal lobe of the anal claw also with a pattern of dark marks. Anal claw (fig. 11) with one auxiliary claw.

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BOOK NOTICES.

Medical Entomology. By ROBERT MATHESON. 8vo. New York (Comstock). 2nd edition, 1950. Pp. 612, 242 figs. Price \$7.50.

There are twenty chapters, of which the first gives brief synopses of some arthropod-borne diseases, and discusses methods of transmission, with definitions of the terms used. This chapter has a long bibliography of works on medical entomology in general, grouped into three sections, of individual papers, journals and books.

Chapters two to four deal with Arthropoda in general, and with Crustacea and Arachnida. There follow fourteen chapters on insects, ten of them dealing with Diptera in considerable detail. Textbooks of medical entomology usually give more prominence either to the entomology or to the medicine, according to the interests of the author; this work maintains an uncommonly equal balance between the two.

There are Keys to Families—including larvae as far as these are known—and in some groups, notably mosquitoes, more detailed keys down to species are included. One long chapter of forty-four pages is devoted to 'myiasis of man and allied conditions' with figures of adults and larvae. Fleas have one chapter and there is one on 'poisonous and urticating arthropods.' A final chapter deals with collecting, preserving and mounting insects.

THE EFFECT OF TEMPERATURE ON THE FINAL INSTAR NYMPHS OF THREE SPECIES OF AUSTRALIAN EPHEMEROPTERA.

By JANET E. HARKER.

(New England University College, Armidale, N.S.W., Australia.)

FROM work done on incipient lethal temperatures of fish (Richet, 1885 ; Plateau, 1872 ; Mayer, 1914 ; Huntsman and Sparks, 1923) there appears to be a relationship between the incipient lethal temperature of a species and the type of habitat in which it occurs. The range of temperatures which the animal can tolerate may also appear to be larger in those which come from environments with a very variable temperature range.

There is, however, a marked degree of ambiguity in the precise meaning which previous writers have implied by the phrases "Incipient Lethal Temperature" and "Thermal Resistance," so that confusion has arisen by indiscriminate use of these two terms. To avoid further confusion in this paper these two terms are intended to describe the following ideas. The incipient lethal temperature is the temperature above which an organism can no longer live for an indefinite period of time ; the thermal resistance is the measure of the ability of an organism to withstand a temperature above the incipient lethal temperature. It will therefore be seen that Whitney's (1939) use of the term "temperature resistance" corresponds with my use of incipient lethal temperature.

Further work done on acclimatization (Loeb and Wasteneys, 1912 ; Jacobs, 1919 ; Hathaway, 1927 ; Fry Hart and Walker, 1946) substantiates this thesis, so that it would be expected that animals which have been living in high-temperature environments would have a higher incipient lethal temperature than those living in relatively low temperature environments.

It has been shown by Whitney (1939) that six species of mayfly nymphs from slow or still water in Great Britain have a higher incipient lethal temperature than those from swift waters. These results suggest at least two questions : (1) Are nymphs from different habitats irreversibly acclimatized ? In other words, if mayfly nymphs are taken from habitats with different mean temperatures and acclimatized to a uniform temperature, will the incipient lethal temperature of the nymphs from each habitat show a relationship to the temperatures of the original habitat ? (2) Are the incipient lethal temperatures of the penultimate instar nymphs correlated with the ability to emerge as a subimago at various temperatures ?

In an attempt to elucidate this problem the following experiments were performed.

METHOD.

Three sets of experiments were performed using two species of mayfly from different habitats, and a third which was found in both these habitats. The species used were *Atalophlebia albiterminata* Tillyard from Dumaresque Creek, Armidale, N.S.W., in a region of rapid flow, *Caenis scotti* Tillyard taken from a small silted pond in the grounds of New England University College, Armidale

(about a quarter of a mile distant from the stream), and *Leptophlebia crassa* Harker which was taken from both habitats. The temperature of the stream varied during the period of collection from 20–24° C., and that of the pond from 25°–32° C. Prior to each experiment each sample was kept at $18 \pm 2^\circ$ C. for a week.

A sample of twenty-five nymphs in the penultimate instar (as far as could be judged from an examination of the wing buds) was chosen for each experiment. The sample was placed in a constant temperature water bath ($\pm 1^\circ$ C.) heated by means of a luminous heating element, which was partially shaded by a tin cylinder. A control experiment using a similar sample of nymphs was placed beside the water bath in approximately the same light intensity, but at a temperature of $18 \pm 2^\circ$ C. This control served as a check both on the possible effect of the light, and on the changes in the rate of emergence with the passage of time. The animals were placed in a beaker containing water which was aerated by having air bubbled through it at intervals. This was partially immersed in the water bath at an initial temperature of 18° C., which was then gradually altered to that required for the experiments. Each experiment was run for a period of seven days. All dead nymphs or emerged subimagines were removed daily.

The difficulty of keeping a constant temperature below 18° C. made it, at the time, impossible to study the effect of low temperatures, but it was found that nymphs kept at 3° C. all died within a few hours. It should be noted that this only occurs in the later stages of the nymphs; earlier instars can tolerate low temperatures.

RESULTS.

From Table I it can be concluded that the percentage of deaths of the nymphs from the higher temperature habitat (the pond) was lower than those from the low temperature habitat (the stream). That is the ratio of percentage of deaths of *Atalophlebia albiterminata* and *Caenis scotti* was 29 : 11 at 30° C. and 40° C., and in the case of *Leptophlebia crassa* at these temperatures the ratio of stream nymph deaths to pond nymph deaths was 13 : 6.

Table III contains a list of the mean temperatures of emergence of the subimagines, and it will be observed from this table that the values for the nymphs from the low temperature habitats are lower than those from the high temperature habitats. *Leptophlebia crassa* has a mean temperature of emergence in the ratio of stream to pond forms 23° C. : 26° C., *A. albiterminata* (stream) to *C. scotti* (pond) 24° C. : 27° C.

TABLE I.—The Percentage Number of Dead Nymphs and Emerged Subimagines at 18°, 25°, 30°, 40° C.

Species . . .	Stream.				Pond.				Stream.				Pond.			
	<i>Atalophlebia albiterminata</i> .				<i>Caenis scotti</i> .				<i>Leptophlebia crassa</i> .				<i>Leptophlebia crassa</i> .			
	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.
	18.	25.	30.	40.	18.	25.	30.	40.	18.	25.	30.	40.	18.	25.	30.	40.
Percentage of dead nymphs after seven days	7	7	21	95	7	7	10	36	2	1	30	100	3	2	15	45
Percentage of subimagines which emerged in seven days	8	82	0	0	10	63	80	9	50	72	22	0	61	60	95	20

TABLE II.—The Percentage Number of Dead Nymphs and Emerged Subimagines During Same Period in Control Experiment at 18° C.

Species	Stream. <i>Atalophlebia albi-terminata</i> .				Pond. <i>Caenis scotti</i> .				Stream. <i>Leptophlebia crassa</i> .				Pond. <i>Leptophlebia crassa</i> .			
Percentage of dead nymphs after seven days	7	6	7	7	7	7	5	6	1	3	1	2	1	2	2	1
Percentage of subimagines which emerged after seven days	15	12	22	10	20	25	27	26	50	65	58	63	65	54	60	61

TABLE III.—The Mean Death and Emergence Temperatures of Pond- and Stream-dwelling Nymphs.

Species.	Habitat.	Range of temperature of habitat.	Mean death temperature.	Mean emergence temperature.
<i>Atalophlebia albitrminata</i> Tillyard	Stream	20–24° C.	36° C.	24° C.
<i>Caenis scotti</i> Tillyard	Pond	25–32° C.	28° C +	27° C.
<i>Leptophlebia crassa</i> Harker	Stream	20–24° C.	33° C.	23° C.
" " " "	Pond	25–32° C.	36° C. +	26° C.

The maximum emergence of subimagines occurs in all the species tested at temperatures close to those of the habitat from which they came, stream insects at 25° C. and pond insects at 30° C.

DISCUSSION.

From these results it appears that the mayfly nymphs used in these experiments from the stream have a lower incipient lethal temperature than those from the pond. The nymphs from the pond also had a lower mean temperature of emergence.

The application of these results to conditions in the field has been mentioned for the breeding aspect, but the death point temperatures are not directly applicable to field conditions because any thermal deaths in nature are more likely to take place under changing temperature conditions.

The nymphs of these two populations of *Leptophlebia crassa* have supposedly both come from the same original population, as the pond and the stream are the only two places in which these nymphs are found in an area of ten square miles. If this is so, then there appears to have been a thermal acclimatization of the two populations to their environments resulting in a difference in thermal tolerance and favourable breeding temperatures. Imagines have been observed flying at distances from both the pond and the stream equivalent to the distance between these two areas, so that there is no complete geographical barrier to interbreeding. From the result obtained, however, it is suggested that the dates of emergence would differ for the two populations, which would cause an effective barrier to interbreeding.

Whether the period spent at 18° C. before the experiments were begun has altered the temperature tolerance range of the two populations of *Leptophlebia crassa* cannot be determined as no experiments were conducted omitting the initial period of acclimatization at 18° C. But it is significant that this acclimatization period has not brought the two populations back to a similar thermal

tolerance range. Previous workers have recorded results of acclimatization when the animals concerned have been kept at the acclimatization temperatures for very short periods of time. The results of these experiments give a marked indication that the time factor is of extreme importance in acclimatization.

SUMMARY.

1. The incipient lethal temperature has been determined for the penultimate instar nymphs of *Atalophlebia albiterminata* Tillyard from a stream, *Caenis scotti* Tillyard from a pond, and *Leptophlebia crassa* Harker from the pond and stream.

2. The final instar nymphs from still water have a higher incipient lethal temperature than those from swift water. The subimagines from still water emerged at a higher temperature than nymphs from running water.

3. The maximum emergence of the subimagines occurs at a temperature close to the mean temperature of the habitat.

4. A barrier to interbreeding is associated with the different emergence temperatures of the two populations of *Leptophlebia crassa*.

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THE EGG PODS OF BRITISH SHORT-HORNED GRASSHOPPERS (ACRIDIDAE).

By N. WALOFF, Ph.D.

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THE descriptions of the egg pods in this paper form one of the necessary steps in the population studies of the British short-horned grasshoppers which are carried out by Dr. O. W. Richards and myself, with the encouragement of Professor J. W. Munro, at the Imperial College Field Station, Silwood Park, Berks.

There are only ten known species of British ACRIDIDAE and five of them, *Omocestus viridulus* (Linnaeus), *Stenobothrus lineatus* (Panzer), *Chorthippus parallelus* (Zetterstedt), *Ch. bicolor* (Charpentier), and *Myrmeleottetix maculatus* (Thunberg), occur at Silwood Park. The other five species were obtained from other localities—*Omocestus ventralis* (Zetterstedt), *Mecostethus grossus*, (Linnaeus) and *Chorthippus vagans* (Eversmann) from New Forest, Hants. We followed the directions of W. R. Frazer (1949) and found the last species in large numbers on Sopley Common, Hants, and on the neighbouring heathlands. *Mecostethus grossus* was collected on Denny Bog and on Matley Bog, Hants. Specimens of *Gomphocerippus rufus* (Linnaeus) were obtained from Box Hill, Surrey, and those of *Chorthippus albomarginatus* (Degeer) from Brentwood, Essex. I should like to thank Mr. Paul Freeman for his kindness in supplying us with the last species.

This paper is divided into the following sections :

1. Characters used in the classification of the egg pods.
2. Key to the pods of British ACRIDIDAE.
3. Descriptions of the egg pods.
4. Notes on the ecology of the egg pods.

1. THE CHARACTERS USED IN THE CLASSIFICATION OF THE EGG PODS OF ACRIDIDAE.

The term "pod" is applied to the mass of eggs, together with the secretions of the accessory glands exuded at the time of oviposition. The outer wall of the pod may be formed of this hardened secretion (fig. 2c) of cemented fragments of plant materials (fig. 1c), or of cemented soil particles (fig. 6c). The apex of the pod is that part through which the nymphs emerge (fig. 1A, fig. 6A), while the base is the opposite end (fig. 1B), towards which the micropyles of the eggs are usually directed. The pods with cemented soil walls may have small easily detachable apical lids (fig. 6D). These are also made of hardened secretion with adhering soil particles. Inside the pods the secretion is of a different nature. It is soft and spongy and lines the walls, forms lamellae between the eggs (fig. 1E), and often a spongy pad above them (fig. 1F). The presence or absence of lid and of the apical pad are diagnostic. The arrangement of the eggs is also characteristic, for example in *Stenobothrus lineatus* they

stand at right angles to the base (fig. 1) and in *Mecostethus grossus* (fig. 10) they are at right angles, or at an angle of 45 degrees to the long axis of the pod. The sculpturing of the egg chorion and its coloration have also been used in contriving this key.

The procedure in describing the pods to some extent follows the lines recommended by Zimin (1938) in his outstanding work on the pods of ACRIDIDAE.

2. KEY TO THE PODS OF BRITISH ACRIDIDAE.

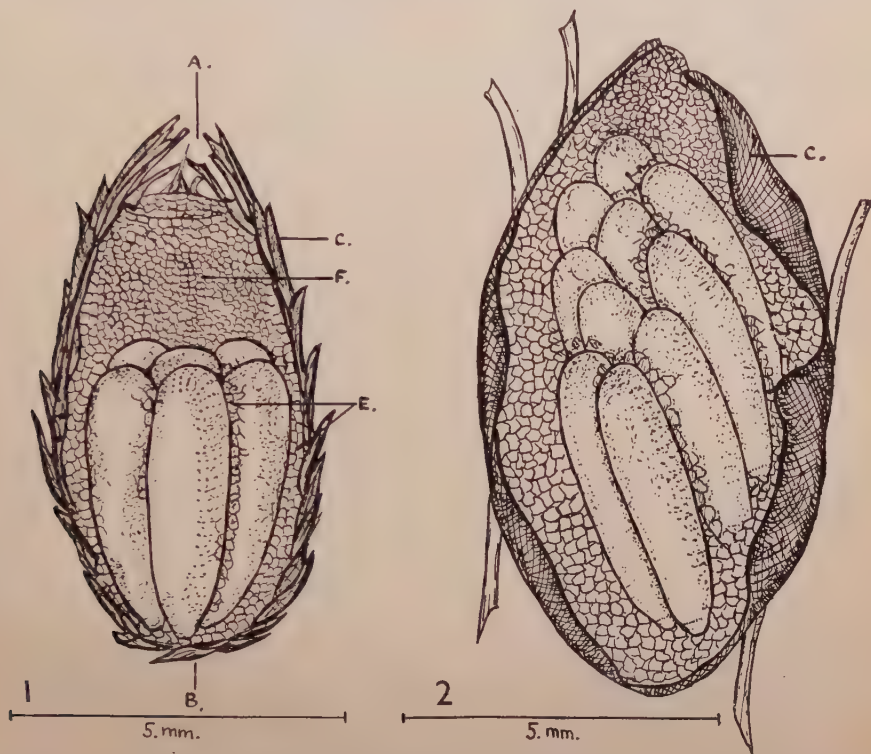
1. Outer wall of cemented fragments of plant materials. Pod small (8.0 mm. average), ovoid. Internally upper half filled with a spongy mass. Eggs in lower half of pod arranged vertically at right angles to base *Stenobothrus lineatus* (Panzer).
 Outer wall of cemented soil particles (2)
 Outer wall of hardened secretions of accessory glands (6)
2. Pod with an apical lid (3)
 Pod without an apical lid (5)
3. Pod large (11.5-16 mm., 13.2 mm. average), cylindrical, straight or curved, with a disc-like apical lid. Egg chorion smooth
 Chorthippus bicolor (Charpentier).
 Pod smaller (usually 10 mm. or less) narrowing at base (4)
4. Lid of pod concave, broad, lined with a thin layer of spongy material.
 Apical spongy pad large. Eggs slender, chorion faintly but distinctly hexagonally sculptured *Gomphocerippus rufus* (Linnaeus).
 Lid of pod flat, small. Apical spongy pad small. Eggs fill practically whole interior of pod; chorion smooth . . . *Chorthippus vagans* (Eversmann).
 Lid convex, hood-like, internally lined with a spongy secretion
 Omocestus ventralis (Zetterstedt).
5. Pod small (9.9 mm. average), usually pear-shaped, attenuated apically.
 Internally no apical pad or a very small one. Egg chorion coarsely hexagonally sculptured *Chorthippus parallelus* (Zetterstedt).
 Pod small (9.3 mm. average), cylindrical, usually curved. Internally there is a large spongy pad (2.5-3 mm. high). Egg chorion without sculpturing, almost smooth *Myrmeleotettix maculatus* (Thunberg).
6. Pod fairly large (10.2 mm. average). Outer opening at apex. Egg chorion dirty whitish buff, finely sculptured *Omocestus viridulus* (Linnaeus).
 Pod smaller (8.5 mm. average). Outer opening at side. Apical spongy pad characteristically coarsely meshed. Egg chorion whitish buff, smooth *Chorthippus albomarginatus* (Degeer).
 Pod large (13.5 mm. average). Contours of eggs clearly visible externally. Eggs arranged at angles of 45-90° to the long axis. Egg chorion tough, reddish-brown, coarsely hexagonally sculptured
 Mecostethus grossus (Linnaeus).

3. DESCRIPTIONS OF THE EGG PODS.

(1) *Stenobothrus lineatus* (Panzer) (fig. 1).

The pod is small, irregularly ovoid, more narrowed at the apex. The outer wall is made of fragments of plant materials and grass cemented together by secretions of the accessory glands and dries quite firm. There is no lid. The most usual number of eggs inside is 6 (see Table I). The eggs are arranged vertically, at right angles to the base. In this arrangement the pod differs from all the other species of British ACRIDIDAE.

Internally the pod is filled with a hardened frothy mass which lines the walls, forming lamellae between the eggs and a pad 2.5-3 mm. above them. This spongy substance is greyish-brown and fairly coarsely meshed. The pad above the eggs, however, is very finely meshed and has the appearance of lighter, buff-coloured interwoven thin threads. Apically the spongy pad is covered by fragments of plant material.



FIGS. 1-2.—(1) Pod of *Stenobothrus lineatus* (Panzer). A, Apex of the pod; B, base of the pod; c, wall of cemented fragments of plant material; E, spongy secretion, lining walls and forming lamellae between the eggs; F, spongy apical pad. (2) Pod of *Omocestus viridulus* (Linnaeus). c, Wall of hardened secretion of the accessory glands.

TABLE I.—Measurements.

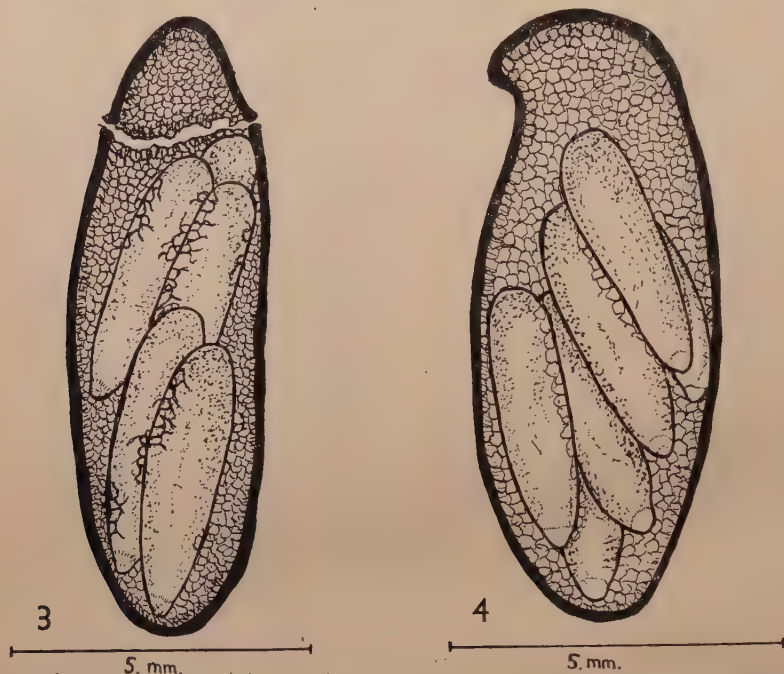
Number examined.	Width in mm.		Length in mm.		Number of eggs in a pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
16 pods	3.5-5.0	4.1	6.0-10.0	8.0	3-8	6.3
9 "	"	"	"	"		
18 eggs	1.0-1.3	1.1	3.9-4.4	4.1		

The eggs are widely rounded anteriorly and narrower at the micropylar end. The chorion is pale greyish-buff with very faint hexagonal sculpturing, which is more discernible towards the micropylar end; the micropyles are brown.

(2) *Omocestus viridulus* (Linnaeus) (fig. 2).

The pod is fairly large and irregular in shape. It is often dilated in the middle and narrowed apically. The outer wall is formed by the hardening of the secretion of the accessory glands. It is dark reddish-brown, very firm and has a leathery appearance. Occasional blades of grass or soil particles may adhere to it. There is no lid and the apical opening is protected by the internal spongy mass.

Internally the spongy mass is shiny, dark reddish- or greyish-brown; it forms a dense pad 1.0–1.5 mm. high above the eggs. The eggs tend to be



FIGS. 3–4.—(3) Pod of *Omocestus ventralis* (Zetterstedt). (4) Pod of *Myrmeleotettix maculatus* (Thunberg).

arranged in three rows sloping towards the side walls of the pod; the most usual number is 10 (see Table II).

TABLE II.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of egg per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
16 pods	4.5–6.5	5.5	7.0–12.5	10.2	4–10	8.0
22 „						
20 eggs	1.0–1.3	1.1	4.0–4.6	4.4		

The eggs are almost straight, narrowing both at the anterior and the micropylar ends. The micropylar cone is slightly constricted above the middle. The chorion is dirty whitish-buff with faint hexagonal sculpturing.

(3) *Omocestus ventralis* (Zetterstedt) (fig. 3).

The pod is short, cylindrical, tapering at both ends; straight or curved. The walls are thin and fairly fragile; they are made of cemented soil particles, as is the hood-like convex lid, which is 2.5–3 mm. high, and is lined internally with the hardened secretion. Internally, the spongy mass is soft, very finely meshed, light buff and shiny. The usual number of eggs is 5 (see Table III).

TABLE III.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
12 pods	3.5–4.5	3.9	9.0–12.0	10.5	5–6	5.1
7 „	„	„	„	„		
10 eggs	1.2–1.4	1.3	4.1–4.4	4.2		

The eggs are slightly curved, rounded anteriorly and narrow at the micropylar cone. The chorion is delicate, whitish buff and shiny. It is smooth, except at the micropylar cone which is irregularly sculptured; the micropyles are pale brown.

(4) *Myrmeleotettix maculatus* (Thunberg) (fig. 4).

The pod is cylindrical and generally slightly bent (sausage-shaped). Externally it resembles that of *Chorthippus parallelus* in having the outer wall made of soil particles cemented together by secretions of the accessory glands, and in not having a lid, but differs from it in being less pear-shaped. The outer walls are thin, but firm.

Internally, the hardened spongy mass is coarse and the meshing is roughly hexagonal. It is pale brown and shiny, forming a pad 2.5–3 mm. high above the eggs. The usual number of eggs is 6 (see Table IV), and they tend to be arranged in two rows slanting towards the walls.

TABLE IV.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
10 pods	3–4.5	3.7	6–10.3	9.3	4–6	5.5
11 „	„	„	„	„		
12 eggs	0.8–1.3	1.1	4.2–4.4	4.3		

The egg chorion is very pale dirty buff, almost smooth, and only lightly sculptured with shallow hexagonal pits. It can be distinguished with a naked eye from the coarsely sculptured chorion of *Ch. parallelus* eggs. The micropyles are dark brown and numerous.

(5) *Chorthippus parallelus* (Zetterstedt) (fig. 5).

The pods are small, cylindrical or pear-shaped drawn to a fine apical point. The outer walls are made of soil particles cemented by secretions of the accessory glands. They are thin but firm. The pod has no lid.

Internally the spongy secretion is coarsely meshed and forms only a small pad of 1 mm. or less above the eggs. The eggs tend to be arranged in three longitudinal rows. The usual number is 10 (see Table V).

TABLE V.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
14 pods	3·6–5·5	4·3	6·1–13·2	9·9	3–10	8·9
28 „	3·6–5·5	4·3	6·1–13·2	9·9		
20 eggs	1·0–1·3	1·1	3·4–4·1	3·9		



FIGS. 5–6.—(5) Pod of *Chorthippus parallelus* (Zetterstedt). (6) Pod of *Chorthippus bicolor* (Charpentier). A, Apex of the pod; B, base of the pod; C, wall of cemented soil particles; D, apical lid of the pod; F, spongy apical pad.

The eggs are straight or slightly curved, rounded at the anterior and conical at the micropylar ends. The chorion is pale brown and shiny, it is coarsely sculptured with low irregular, hexagonally arranged ridges. This coarse sculpturing distinguishes *Ch. parallelus* eggs from all the other species with pod walls made of soil particles. The sculpturing is even clearer below the ring of micropyles which are blackish-brown.

(6) *Chorthippus bicolor* (Charpentier) (fig. 6).

The pod is cylindrical and slightly curved (sausage-shaped) although it may be straight and/or dilated at the base. It is considerably larger than that of *Ch. parallelus* or of *Myrmeleotettix maculatus*, but agrees with them in having thin, firm walls of soil particles cemented together by the accessory glands. It differs, however, from the pods of the above species in having a thin disc-like lid, about 2 mm. in diameter.

Internally the spongy mass is finely meshed and is pale golden and shiny. There is a fairly large pad above the eggs which can be 2-5 mm. high. The eggs are arranged in 2 or 3 rows, slanting towards the walls. The usual number of eggs is 14 (see Table VI).

TABLE VI.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
13 pods	5-6.5	5.6	11.5-16	13.2	7-14	11.2
18 "						
20 eggs	0.9-1.2	1.0	3.9-4.5	4.2		

The eggs are narrowed at the micropylar end. The chorion is pale dirty fawn and shiny; it is not sculptured. The micropyles are brown, small and numerous.

(7) *Chorthippus albomarginatus* (Degeer) (fig. 7).

The pods are small, very irregular in shape, sometimes very wide in the middle. The outer wall is formed by the hardened secretion of the accessory glands; it is dark brown or black. Externally the pods resemble those of *Omocestus viridulus*, but they can be distinguished by their smaller size, and in having the opening at the side instead of at the apex. There is no lid and the opening is protected by a film of hardened secretion.

Internally, the spongy mass is shiny brown or straw-brown and forms a small pad 1-1.5 mm. above the eggs. The meshing of the pad is irregular and very large; in the rest of the pod it is fine. The eggs tend to be arranged in 2 or 3 rows sloping towards the walls; the number of eggs is variable (see Table VII).

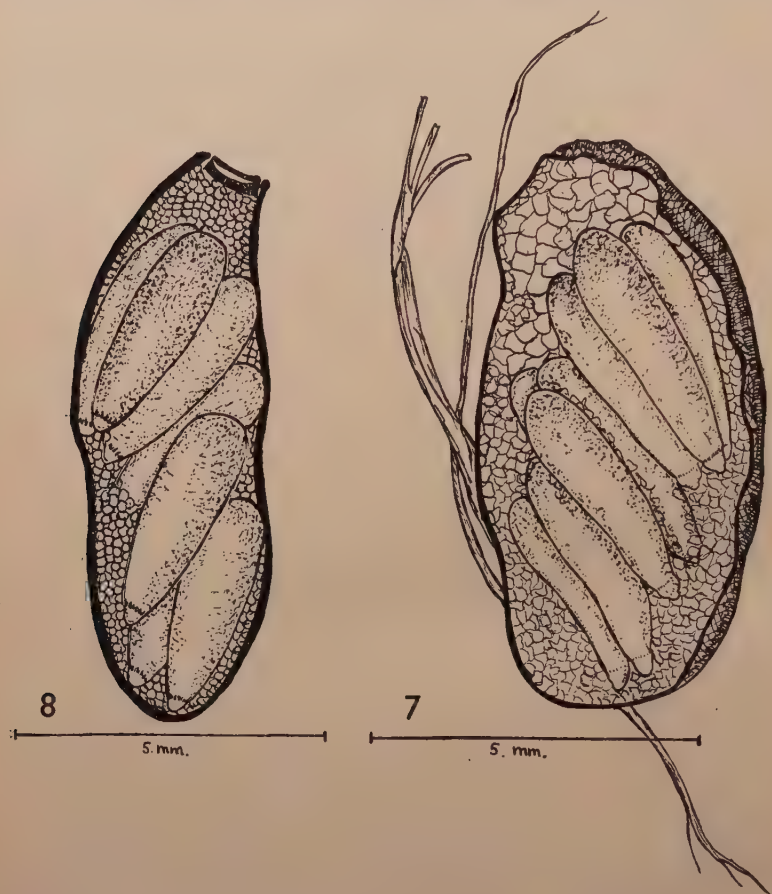
TABLE VII.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
6 pods	4.0-6.0	4.6	7.5-12.0	8.5	3-10	6.
6 "						
13 eggs	0.9-1.2	1.1	3.8-4.5	4.1		

The eggs are straight or slightly bent, narrowing at the anterior and at the micropylar ends. The micropylar cone has a slight constriction at base. The chorion is dirty whitish buff and quite smooth; the micropyles are brown.

(8) *Chorthippus vagans* (Eversmann) (fig. 8).

The pod is short, straight or only slightly bent. The walls are made of soil particles cemented by secretions of the accessory glands; they are very



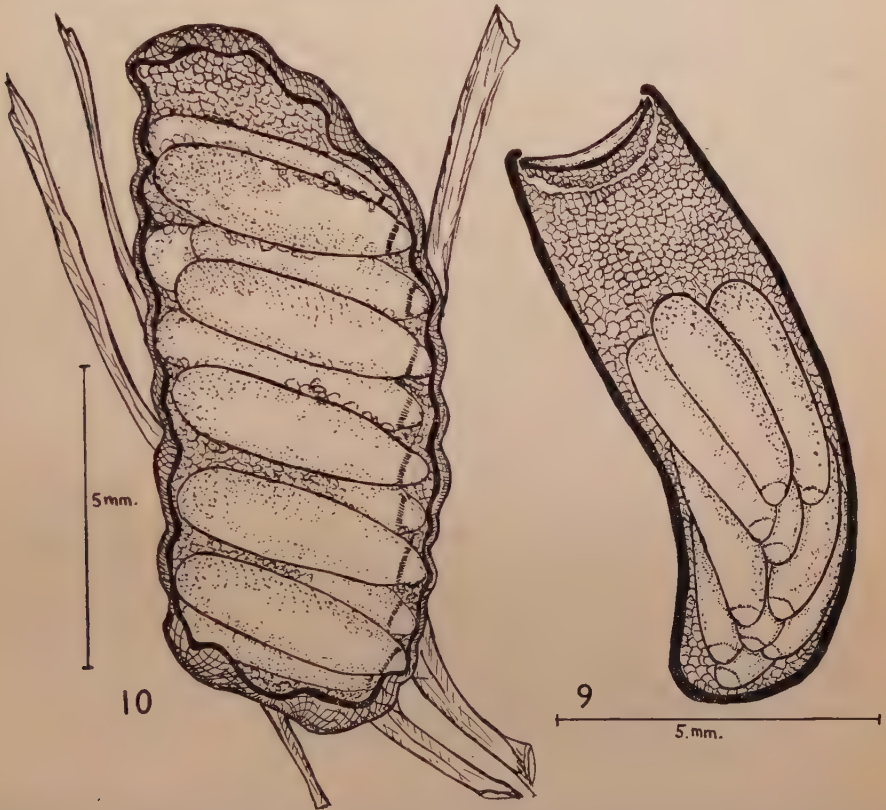
FIGS. 7-8.—(7) Pod of *Chorthippus albomarginatus* (Degeer). (8) Pod of *Chorthippus vagans* (Eversmann).

thin, but firm. The apex of the pod is generally protected by a small concave lid 1.5–2.0 mm. in diameter. In two of the twelve pods examined the lid was absent and the apices were drawn to a fine point as in *Ch. parallelus* pods. Internally, the spongy mass is soft, buff-brown and shiny. It is regularly hexagonally meshed, and forms a small pad 1 cm. long above the eggs. Practically the whole pod is filled with the eggs; there is very little, or no spongy material between them.

TABLE VIII.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
10 pods	3.0-4.0	3.6	7.0-12.0	8.9	5-8	6.2
8 "						
10 eggs	1.2-1.5	1.4	4.2-4.7	4.5		

The eggs are straight or only slightly curved, rounded at anterior end, conical at the micropylar end. The chorion is smooth and dirty buff-coloured. The micropylar cone is small and the micropyles brown.



FIGS. 9-10.—(9) Pod of *Gomphocerippus rufus* (Linnaeus). (10) Pod of *Mecostethus grossus* (Linnaeus).

(9) *Gomphocerippus rufus* (Linnaeus) (fig. 9).

The pod is fairly short and wide. It tends to be cylindrical and bent, narrowing at the base and apex. The walls are made of soil particles cemented by secretions of the accessory glands; they are thin, but firm. The concave lid is well differentiated and measures 2-3 mm. It is smooth on top and is lined with a hardened spongy secretion.

Internally the spongy mass is soft; it is brown and shiny. It forms a pad

2.5-3 mm. above the eggs and coarsely meshed lamellae between the eggs. These lamellae are firm, so that when the eggs are removed, the pod appears divided into a series of chambers. The usual number of eggs is 10 (see Table IX).

TABLE IX.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
10 pods .	4.0-5.5	4.4	7-11.5	9.5	5-10	8.8
9 " .						
20 eggs .	0.8-1.1	1.0	3.6-4.0	3.8		

The eggs are slightly curved and slender; they are rounded both at the anterior and the narrow micropylar ends. The chorion is dirty white buff with a delicate, though well marked, sculpturing of regular, hexagonal shallow pits surrounded by low ridges. This sculpturing is not so obvious as in *Ch. parallelus* and differs from the latter in the regularity of its hexagons. The micropyles are pale brown.

(10) *Mecostethus grossus* (Linnaeus) (fig. 10).

The pods are large and elongated. The outer wall is made of brown, hardened secretion of the accessory glands. There is no lid and the apex is usually attenuated. The contours of the eggs are clearly visible externally.

Internally the spongy mass is pinkish-brown and finely meshed. The eggs are arranged either in horizontal rows or at an angle of 45-60° to the long axis.

TABLE X.—Measurements.

Number examined.	Width in mm.		Length in mm.		Number of eggs per pod.	
	Range.	Mean.	Range.	Mean.	Range.	Mean.
6 pods .	6-6.5	6.3	10-16	13.5	11-14	12.6
3 " .						
10 eggs .	1.5-1.8	1.6	6.1-7.0	6.4		

The chorion is tough and reddish-brown; it is coarsely sculptured with hexagonal pits. The micropylar cone is short and rounded and the micropyles form a continuous brownish-black ring above it.

4. NOTES ON THE ECOLOGY OF EGG PODS.

There are only a few species of British short-horned grasshoppers, but the variability in the structure of their egg pods is a reflection of the different types of behaviour associated with oviposition. Six of the species lay in the superficial layers of the soil (*Chorthippus bicolor*, *Ch. parallelus*, *Ch. vagans*, *Omocestus ventralis*, and *Gomphocerus rufus*), one just above the roots of grasses (*Stenobothrus lineatus*) and three at the bases of grass blades (*Omocestus viridulus*, *Chorthippus albomarginatus*, and *Mecostethus grossus*). The distribution of the pods of the five species at Silwood Park have been studied by intensive soil sampling. The pods of *Omocestus viridulus* and of *Stenobothrus lineatus* were almost exclusively found in the grassy soil covering, although in a few

instances they were recorded from bare ground as well, for no soil is so denuded as not to have a few tufts of grass growing on it. Although *Chorthippus parallelus* usually lays on bare soil, it can also oviposit in grass covered soil, while *Myrmeleotettix maculatus* and *Chorthippus bicolor* oviposit only on bare soil. The habits of the other five species were studied in cages. The grasshoppers were presented with oviposition sites of bare soil, tufts of grass, and, in the case of the hygrophilous *Mecostethus grossus*, with tufts of moist *Sphagnum* as well.

The oviposition habits of grasshoppers largely determine their distribution and it is interesting to note that ant mounds of *Lasius flavus* (Fabricius) can provide oviposition sites for both *Chorthippus parallelus* and *Ch. bicolor* in areas which would otherwise be unsuitable to them. In a field with dense vegetation, we have found pods of *Ch. bicolor* exclusively in these ant mounds. Large numbers of egg pods of *Ch. bicolor* were also found in artificial earthen mounds introduced into the field, but none of *Ch. parallelus*. It would seem that the latter species prefers firmer bare ground for oviposition. Although the texture of the soil thus appears important, it is doubtful that its actual composition has any direct effect on the laying habits, as the species which are found on the light sandy soil of Silwood Park also occur in large numbers on the chalk downs in Surrey (e.g. Box Hill).

Zimin (1938) in his excellent account of the egg pods of ACRIDIDAE shows that the ecological requirements of the adults are reflected in the morphology and the position of the pods, i.e. :

1. Hygrophilous ACRIDIDAE lay pods in the vegetation just above the soil.
2. Mesophilous lay in the superficial layers of the soil.
3. Xerophilous lay pods several inches below the soil surface.

This classification is somewhat parallel to that applied by Raunkiaer (1937) to different plant life forms. In both cases the delicate growing part of the organism (in this case the eggs), is protected at different levels above and below the ground level in different geographical regions. It is quite striking that the majority of the Southern species studied by Zimin do produce pods of the xerophilous type; moreover they are characterized by a very large apical spongy pad (e.g. in *Locusta migratoria* (L.)) which presumably reduces the water loss by evaporation. None of these occur in Great Britain and the ten species of ACRIDIDAE lay either in the superficial soil layers, or in the grass cover just above it. On the morphology of their egg pods one can arrange the British species in the following way :

1. Hygrophilous.	2. Mesophilous.	3. Xerophilous.
<i>Omocestus viridulus</i> .	<i>Omocestus ventralis</i> .	
<i>Chorthippus albomarginatus</i> .	<i>Myrmeleotettix maculatus</i> .	
<i>Mecostethus grossus</i> .	<i>Chorthippus vagans</i> .	None.
	<i>Ch. parallelus</i> .	
	<i>Ch. bicolor</i> .	
	<i>Gomphocerippus rufus</i> .	
	<i>Stenobothrus lineatus</i> .	

These groups are by no means rigid, as the limits within which a species can exist appear large and overlapping. For instance, although *Chorthippus parallelus*, usually described as the common grasshopper of the meadows, falls into the mesophilous group, we have found it with *Mecostethus grossus* in Denny Bog in the New Forest, and *Stenobothrus lineatus* which falls in between groups 1 and 2, forms large and characteristic colonies with the distinctly hygrophilous *M. grossus* in Puy de Dôme region of France. It is interesting to note that on the basis of the size of the spongy apical pad above the eggs, *Chorthippus bicolor* and *Gomphocerippus rufus* show the greatest tendency towards xerophily of all the British species. It is also apparent that the structure of the pod is not a generic character, but rather an ecological one.

The complete absence of species with deeply laid pods in this country is also of interest and one is tempted to speculate as to the causes. For although the pods of the xerophilous species are to some extent protected from water loss by the depth at which they are laid and by the long apical pad, it is also these pods which would tend to be waterlogged for longer periods than those nearer the soil surface. Moreover it is doubtful if the soil temperatures at the depth of a few inches are sufficiently high for any length of time, in this climate, to allow for the development of the eggs. It is possible that these causes, amongst others, prevent the establishment of some of the potential immigrants and account for the paucity of the species in Great Britain.

SUMMARY.

The egg pods of the ten species of the British ACRIDIDAE are described and figured and the key for their identification is given. The variation in the egg number per pod is noted, and the possible relation between the structures of the pods and ecology of the grasshoppers is discussed.

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